wavelength at T < 2°K agrees well (within several per cent) with the formula $\lambda = (2\pi s/\omega)\sqrt{\rho_s/\rho}$ corresponding to complete dragging of the normal component. At sufficiently low temperatures, the depth of penetration increases, since the influence of the normal component on the oscillations becomes negligible. We note that, according to Reatto [5], the oscillations become damped, albeit very weakly, even at absolute zero temperature, owing to the finite propagation velocity of the interaction in the helium.

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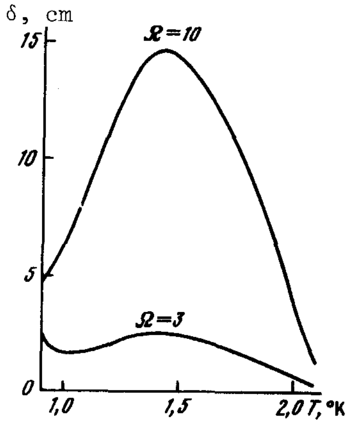

Penetration depth of transverse wave at ω = 0.1 rad

EXCITATION OF NUCLEAR LEVELS BY ELECTRONS AND HADRONS AT HIGH ENERGY

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Many experimental results on the cross sections for the excitation of nuclear levels by high-energy protons have been reported recently [1, 2]. The present paper aims to show that at high energy there exists a unique connection between the excitation cross sections of a definite series of nuclear transitions in electron and hadron beams. This series includes transitions that can be realized by exchange of states with natural parity in the t-channel, i.e., transitions of the type $0^+ \to 0^+$, 1^-, 2^+, 3^-, etc. Transitions of this type can be excited upon exchange of the vacuum quantum numbers in the t-channel, so that their excitation cross sections do not decrease with increasing energy [3].

To obtain the sought connection, we consider the scattering of a hadron by a nucleus within the framework of the multichannel optical model

$$(\nabla^2 + k_\alpha^2)\Psi_\alpha(\mathbf{r}) = \sum_{\alpha'} V_{\alpha\alpha'}(\mathbf{r})\,\Psi_{\alpha'}(\mathbf{r}), \tag{1}$$

where Ψ_α is the wave function of a system consisting of a hadron and a target nucleus in the state α. A similar model was used to calculate the excitation cross sections of hadrons interacting with nuclei. In our case, the optical potential is given by

$$U_{\alpha\alpha'}(\mathbf{r}) = -4\pi f(0) A \rho_{\alpha\alpha'}(\mathbf{r}), \tag{2}$$

where f(0) is the amplitude of the elastic hadron-nucleon scattering, and $\rho_{\alpha\alpha'}(\vec{r})$ is the single-particle density matrix, defined in terms of the form factor with the aid of the Fourier transformation

$$\rho_{\alpha\alpha'}(\mathbf{r}) = \int e^{-i\mathbf{q}\mathbf{r}} S_{\alpha\alpha'}(\mathbf{q}) \frac{d^3q}{(2\pi)^3}, \tag{3}$$

$$S_{\alpha\alpha'}(\mathbf{q}) = \frac{1}{A}\int \left(\sum_{i=1}^{A} e^{i\mathbf{q}\mathbf{r}_i}\right) \Psi^*_{\alpha'}(\mathbf{r}_1, \ldots, \mathbf{r}_A) \times \Psi_\alpha(\mathbf{r}_1, \ldots, \mathbf{r}_A)\, d^3\mathbf{r}_1 \ldots d^3\mathbf{r}_A. \tag{4}$$

When considering any transition i → f we shall, by virtue of the smallness of the off-diagonal elements of the matrix ρ in comparison with the diagonal ones, take the potential V_{if} into account only in first order perturbation theory, while the potentials V_{ii} and V_{ff} will be taken exactly. In the eikonal approximation $\Psi_\alpha(\vec{r}) = [\exp(ik_\alpha z)]\phi_\alpha(\vec{b}, z)$ the problem the reduces to the solution of two first-order linear differential equations for ϕ_i and ϕ_f. After solving this system we can find the following expression for the amplitude of the inelastic $i \to f$ transition in the lab

$$F_{if}(q) = -\frac{1}{4\pi}\int e^{iqb}\, d^2b \left[\int \exp\left(\int_{z'}^{\infty} \frac{1}{2ik} V_{ff}(b, z)\, dz\right) \times \right.$$
$$\left. \times\, V_{if}(b, z')\exp\left(\int_{-\infty}^{z'} \frac{1}{2ik} V_{ii}(b, z)\, dz\right) dz'\right]. \tag{5}$$

The normalization is such that $d\sigma/d\Omega = |F_{if}(\vec{q})|^2$.

We now assume that there is little difference between the densities of the initial and final states, i.e., that $\rho_{ii} \simeq \rho_{ff}$. Formula (5) then becomes

$$F_{if}(q) = Af(0)\left[S_{if}(q) - \frac{1}{2\pi ik}\int d^2q' S_{if}(q')F_{ii}(q - q')\right]. \tag{6}$$

The amplitude of the $i \to f$ transition is thus expressed in terms of the transition form factor $S_{if}(\vec{q})$ and the elastic-scattering amplitude $F_{ii}(\vec{q})$.

Formula (6) is valid under the following conditions: a) $A \gg 1$; b) the level f can be excited without transfering any quantum numbers in the t-channel, merely as a result of excitation of the orbital momentum; c) the cross sections for the excitation of levels adjacent to the given one are not anomalously large.

Condition (b) is satisfied if the exchange in the t-channel is effected by states with the quantum numbers of vacuum or the ω meson without change of spin or isospin [3]. Condition (c) is satisfied for levels that are most strongly excited at high energies, for example the 2^+ level of C^{12} or 3^- of O^{16} (see [1, 2]). For weakly-excited levels, it may be important to take into account the transition through an intermediate state of a strongly-excited level. In the latter case it is necessary to solve at least a system of three equations of the type (1), and not two as above. Such a situation may be realized, for example, for the 0^+ 6.06-MeV level of the O^{16} nucleus.

When condition (b) is satisfied, the form factor $S_{if}(\vec{q})$ coincides with the Coulomb electromagnetic form factor corresponding to the same transition that is excited in inelastic scattering of electrons by the given nucleus.

Using expression (6) and changing over to the impact-parameter representation, we obtain the following formula for the total cross section for the inelastic scattering of a hadron by a nucleus with excitation of the transition $i \to f$:

$$\sigma_{if} = \frac{\sigma_{NN}^2(1 + \alpha^2)}{4} A^2 \int |\rho_{if}(b)|^2\, |1 - \Gamma(b)|^2 d^2b. \tag{7}$$

Here

$$\rho_{if}(b) = \int \frac{d^2q}{(2\pi)^2} S_{if}(q)\, e^{-iqb}, \tag{8}$$

and the remaining notation is the same as in [5, 6]. The profile function $\Gamma(\vec{b})$ is connected with the elastic-scattering amplitude, $\Gamma(\vec{b}) = (2\pi/ik)F_{ii}(\vec{b})$. The total elastic cross section is given by

$$\sigma_{ii} = \left(\frac{2\pi}{k}\right)^2 \int d^2b\, |F_{ii}(b)|^2. \tag{9}$$

Since $1 - \Gamma(\vec{b})$ characterizes the transparency of the nucleus and reaches unity outside its volume, while $\rho_{if}(\vec{b})$ differs from zero inside the volume of the nucleus, it can be seen from (7) that the entire inelastic process takes place on the surface of the nucleus. Therefore σ_{if} can yield important information on the structure of the nuclear surface. This circumstance was noted earlier in [6] and [2].

As indicated above, the cross sections for the excitations of the levels satisfying the condition (b) do not decrease with increasing energy [3]. Thus, formulas (6) and (7) connect the cross sections of the most noticeably excited levels in high-energy hadron beams with the corresponding electromagnetic-excitation cross sections.

We note in conclusion that the method used by us is actually equivalent to the eikonal approximation in the distorted wave method, which has been sucessfully used to describe elastic scattering of protons by C^{12} and O^{16} nuclei in [7, 8]. There, however, model formulas were used for the wave functions of the nuclei, and no connection was established between the cross sections of the electromagnetic and hadronic processes.

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NONEQUILIBRIUM COMPOSITION OF NEUTRON-STAR SHELLS AND NUCLEAR ENERGY SOURCES

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1. The question of the chemical composition of matter at densities $\rho = 10^{10} - 10^{14}$ g/cm^3, corresponding to shells of neutron stars, was considered recently [1, 2]. However, it is assumed in these as well as in earlier papers that the matter of the neutron star is in a lower energy state. We show in the present paper, on the basis of an analysis of the process of neutron-star formation, that the state of complete minimum of the energy is not reached in neutron-star shells at densities $10^{14} \leq \rho \leq 10^{11}$ g/cm^3. A large excess of nonequilibrium neutrons is produced, and their reserve of nuclear energy could ensure a neutron-star luminosity at a level $\sim 10^{36}$ erg/sec for $\sim 3\times 10^5$ years.

2. According to present-day concepts, the formation of a neutron star should occur during a collapse process accompanied by a subsequent expansion of the shell and observable supernova explosion [3]. The matter making up the shell of the neutron star should go during the collapse proces through a stage of temperatures T and densities ρ much higher than in a stationary star. During the stage of higher ρ and T there are produced neutrons and superheavy nuclei, the neutrons making up the bulk of the matter [4].

During the course of the expansion of the outer layers of the neutron stars and establishment of the stationary state, the nuclei rapidly capture neutrons, undergo β^- decay, and heavy nuclei are produced [5, 6]. At large A and Z, the nuclei become unstable against spontaneous fission and alpha-particle emission. An increase in the number of neutrons in the nucleus stabilizes these instabilities, but when the neutron excess becomes very strong the energy Q_n of detachment of the last neutron becomes equal to zero and further neutron capture becomes impossible. Under normal conditions, such nuclei are β^--unstable, but in the presence of degenerate electrons with large Fermi energy ε_{Fe} the β^- decay is forbidden.

The figure shows on the (A, Z) plane the line ab where $Q_n \simeq 0$. The values of A and Z on this line were calculated for several nuclei in [7]; it is usually assumed [3] that $Z = A/4$ on